

XXI. *New Fundamental Experiments upon the Collifion of Bodies.* By Mr. John Smeaton, F. R. S. in a Letter to Sir Joseph Banks, Bart. P. R. S.

Read April 18, 1782.

TO SIR JOSEPH BANKS, BART. P. R. S.

S I R,

THE subjects of the inclosed tract have been the object of my confideration for many years past; and as they contain some matters that have not only been variously reasoned about, but variously concluded upon; if what is contained therein shall appear of such a nature as either to establish truth, as it appears to me; or to prompt some more able person, in reviewing the subject, to shew what links in my chain of reasoning thereon are defective, so as to establish the whole doctrine of moving bodies upon one plain consistent basis, my end will be equally answered in offering them to you, to be laid before the Royal Society, in case you shall think that the importance of the subject shall merit the same: furthermore, I hope to be forgiven, if in some parts of this paper I have expressed myself with more pointedness than I might have done, for I declare, that it was solely owing to my earnestness that the subject of mechanic motions and powers should be fully and freely investigated, and established upon grounds that shall be uncontrovertible.

I have the honour to be, &c.

Gray's-Inn,
April 18, 1782.

VOL. LXXII.

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IT is universally acknowledged, that the first simple principles of science cannot be too critically examined, in order to their being firmly established; more especially those which relate to the practical and operative parts of mechanics, upon which much of the active business of mankind depends. A sentiment of this kind occasioned my tract upon *Mechanic Power*, which was published in the Philosophical Transactions, vol. LXVI. for the year 1776. What I have now to offer was intended as a supplement thereto, and the experiments were then, in part, tried; but the completion thereof was deferred at that time, partly from want of leisure; partly to avoid too great a length of the paper itself; and partly to avoid the bringing forward too many points at once. My present purpose is to shew, that the true doctrine of the *collision of bodies* hangs as it were upon the same hook, as the doctrine of the gradual generation of motion from rest, considered in that paper; that is, that whether bodies are put into gradual motion, and uniformly accelerated from rest to any given velocity; or are put in motion, in an instantaneous manner, when bodies of any kind strike one another; the motion, or sum of the motions produced, has the same relation to mechanic power therein defined, which is necessary to produce the motion desired. To prove this, and at the same time to shew some capital mistakes in principle, which have been *assumed* as indisputable truths by men of great learning, is the reason of my now pursuing the same subject.

I do not mean to point out the particular mistakes which have been made by particular men, as that would lead me into too great a length: I shall therefore content myself with observing, that the laws of collision, which have been investigated by mathematical philosophers, are principally of three kinds; *viz.* those relating to bodies perfectly *elastic*; to bodies perfectly

perfectly unelastic, and perfectly *soft*; and to bodies perfectly unelastic, and perfectly *hard*. To avoid prolixity, I shall consider in each, only the simple case of two bodies which are equal in weight or quantity of matter striking one another. Respecting those which are perfectly elastic, it is universally agreed, that when two such bodies strike one another, no motion is lost; but that in all cases, what is lost by one is acquired by the other: and hence, that if an elastic body in motion strikes another at rest, upon the stroke the former will be reduced to a state of rest, and the latter will fly off with an equal velocity.

In like manner, if a non-elastic *soft* body strikes another at rest, they neither of them remain at rest, but proceed together from the point of collision with exactly one half of the velocity that the first had before the stroke; this is also universally allowed to be true, and is fully proved by every good experiment upon the subject.

Respecting the third species of body, that is, those that are non-elastic, and yet perfectly hard; the laws of motion relating to them, as laid down by one species of philosophers, have been rejected by another; the latter alledging, that there are no such bodies to be found in nature whereon to try the experiment; but those who have laid down and assigned the doctrine that would attend the collision of bodies of this kind (if they could be found) have universally agreed, that if a non-elastic *hard* body was to strike another of the same kind at rest, that, in the same manner as is agreed concerning non-elastic soft bodies, they neither of them would remain at rest, but would in like manner proceed from the point of collision, with exactly one half of the velocity that the first had before the stroke: in short, they lay it down as a rule attending all non-elastic bodies, whether hard or soft, that the velocity after the stroke will

be the same in both, *viz.* *one half* of the velocity of the original striking body.

Here is therefore the assumption of a principle, which in reality is proved by no experiment, nor by any fair deduction of reason that I know of, *viz.* that the velocity of non-elastic *hard* bodies after the stroke must be the same as that resulting from the stroke of non-elastic *soft* bodies; and the question now is, whether it is true or not?

Here it may be very properly asked, what ill effects can result to practical men, if philosophers should reason wrong concerning the effects of what does not exist in nature, since the practical men can have no such materials to work upon, or misjudge of? But it is answered, that they who infer an equality of effects between the two sorts, may from thence be misled themselves, and in consequence mislead practical men in their reasonings and conclusions concerning the sort with which they have abundant concern, to wit, the non-elastic *soft bodies*, of which water is one, which they have much to do with in their daily practice.

Previous to the trying my experiment on mills I never had doubted the truth of the doctrine, that the same velocity resulted from the stroke of both sorts of non-elastic bodies; but the trial of those experiments made me clearly see at least the inconclusiveness, if not the falsity of that doctrine: because I found a result which I did not expect to have arisen from either sort; and for the which, when it appeared from experiment, I could see a substantial reason why it should take place in one sort, and that it was impossible that it could take place in the other; for if it did, the bodies could not have been perfectly *hard*, which would be contrary to the hypothesis. Of this deduction I have given notice in my said tract on mills, published

lished in the Philosophical Transactions, vol. LI. for the year 1759*.

It may also be said, that since we have no bodies perfectly elastic, or perfectly unelastic and *soft*, why should we expect and bodies perfectly unelastic and *hard*? Why may not the effects be such as should result from a supposition of their being *imperfectly elastic* joined with their being *imperfectly hard*? But here I must observe, that the supposition appears to be a contradiction in terms.

We have bodies which are so nearly perfectly elastic, that the laws may be very well deduced and confirmed by them; and the same obtains with respect to non-elastic *soft* bodies; but concerning bodies of a mixed nature, which are by far the greatest number, so far as they are wanting in elasticity, they are *soft*, and *bruise*, *yield*, or *leave a mark* in collision; and so far as they are not perfectly soft they are elastic, and observe a mixture of the law relative to each; but imperfectly elastic bodies, imperfectly hard come in reality under the *same description* as the former mixed bodies: for so far as they are imperfectly hard they are soft, and either *bruise* and *yield*, or leave a mark in the stroke; and so far as they want perfect elasticity, they are non-elastic; that is to say, they are bodies imperfectly elastic, and imperfectly soft; and in fact I have never yet seen any bodies but what come under this description. It seems, therefore, that respecting the *hardness* of bodies they differ in degrees of it, in proportion as they have a greater degree of tenacity or cohesion; that is, are further removed from perfect

* “ The effect, therefore, of overshot wheels, under the same circumstance of quantity and fall, is at a medium double to that of the undershot: and as a consequence thereof, that *non-elastic bodies, when acting by their impulse or collision, communicate only a part of their original power; the other part being spent in changing their figure in consequence of the stroke.*” Phil. Trans. vol. LI. p. 133.

softness, at the same time that their elastic springs, so far as they reach, are very stiff; and hence we may (by the way) conclude, that the same mechanic power that is required to change the figure in a *small degree* of those bodies that have the popular appellation of *hard bodies*, would change it in a *great degree* in those bodies that approach towards softness, by having a small degree of tenacity or cohesion. In the former kind we may rank the harder kinds of *cast iron*, and in the latter, *soft tempered clay*.

While the philosophical world was divided by the dispute about the *old* and *new opinion*, as it was called, concerning the powers of bodies in motion, in proportion to their different velocities: those who held the old opinion contending, that it was as the velocity *simply*, asked those of the new, How, upon their principles, they would get rid of the conclusions arising from the doctrine of unelastic perfectly hard bodies? They replied, They found no such bodies in nature, and therefore did not concern themselves about them. On the other hand, those of the new opinion asked those of the old, How they would account for the case of non-elastic soft bodies, where, according to them, the whole motion lost by the striking body was retained in the two after the stroke (the two bodies moving together with the half velocity), though the two non-elastic bodies had been bruised and changed their figure by the stroke; for, if no motion was lost, the change of figure must be an effect without a cause? To obviate this, those of the old opinion seriously set about proving, that the bodies might change their figure, without any loss of motion in either of the striking bodies.

Neither of these answers have appeared to me satisfactory, especially since my mill experiments: for with respect to the first, it is no proper argument to urge the impossibility of find-

ing the proper material for an experiment, in answer to a conclusion drawn from an abstract idea. On the other hand, if it can be shewn, that the figure of a body can be changed, without a *power*, then, by the same law, we might be able to make a *forge hammer* work upon a mass of soft iron, without any other power than that necessary to overcome the friction, resistance, and original *vis inertiae*, of the parts of the machine to be put in motion: for, as no progressive motion is given the mass of iron by the hammer (it being supported by the anvil), no power can be expended that way; and if none is lost to the hammer from changing the figure of the iron, which is the only effect produced, then the whole power must reside in the hammer, and it would jump back again to the place from which it fell, just in the same manner as if it fell upon a body perfectly elastic, upon which, if it did fall, the case would really happen: the power, therefore, to work the hammer would be the same, whether it fell upon an elastic or non-elastic body; an idea so very contrary to all experience, and even apprehension, of both the philosopher and vulgar artist, that I shall here leave it to its own condemnation.

As nothing, however, is so convincing to the mind as experiments obvious to the senses, I was very desirous of contriving an experiment in point; and as I saw no hopes of finding matter to make a *direct* experiment, I turned my mind towards an indirect one; so circumscribed, however, as to prove incontestably, that the result of the stroke of two non-elastic perfectly hard bodies could not be the same as would result from the collision of two soft ones; that is, if it can be *bona fide* proved, that *one half* of the original power is lost in the stroke of soft bodies by the change of figure (as was very strongly suggested by the mill experiments); then since no such loss

can happen in the collision of bodies perfectly hard, the result and consequence of such a stroke must be *different*.

The consequence of a stroke of bodies perfectly hard, but void of elasticity, must doubtless be different from that of bodies perfectly *elastic*: for having no spring the body at rest could not be driven off with the velocity of the striking body, for that is the consequence of the action of the spring or elastic parts between them, as will be shewn in the result of the experiments; the striking body will therefore not be stopped, and as the motion it loses must be communicated to the other, from the equality of action and re-action, they will both proceed together, with an equal velocity, as in the case of non-elastic soft bodies: the question, therefore, that remains is, what that *velocity must be*?—It must be greater than that of the non-elastic soft bodies, because there is no mechanical power lost in the stroke. It must be less than that of the striking body, because, if equal, instead of a *loss* of motion by the collision, it will be doubled. If, therefore, non-elastic soft bodies lose half their motion, or mechanical power, by change of figure in collision, and yet proceed together with half the velocity, and the non-elastic hard bodies can lose *none* in any manner whatever; then, as they must move together, their velocity must be such as to preserve the equality of the mechanic power, *unimpaired*, after the stroke the same as it was before it.

For example, let the velocity of the striking body before the stroke be 20, and its mass or quantity of matter 8; then, according to the rule deduced from the experiments in the tract on *Mechanic Power* (see exp. third and fourth) that power will be expressed by $20 \times 20 = 400$, which $\times 8 = 3200$; and if half of it is lost in the stroke, in the case of non-elastic soft bodies, it will be reduced to 1600; which $\div 16$ the double quantity of matter, will give 100 for the square of their velocity; the

square root of which being 10, will be the velocity of the two non-elastic soft bodies after the stroke, being just one half of the original velocity, as it is constantly found to be. But in the non-elastic hard bodies, no power being lost in the stroke, the mechanic power will remain after it, as before it, = 3200; this, in like manner, being divided by 16, the double quantity of matter, will give 200 for the square of the velocity, the square root of which is 14. 14, &c. for their velocity after the stroke, which is to 10, the velocity of the non-elastic soft bodies after the stroke, as the square root of 2 to 1; or as the diagonal of a square to its side.

It remains, therefore, now to be proved, that precisely half of the mechanic power is *lost* in the collision of non-elastic soft bodies; for which purpose my mind suggested the following reflections. In the collision of elastic bodies the effect seemingly instantaneous, is yet performed in *time*; during which time the natural springs residing in elastic bodies, and which constitute them such, are bent or forced, till the motion of the striking body is divided between itself and the body at rest; and in this state the two bodies would then proceed together, as in the case of non-elastic soft bodies; but as the springs will immediately restore themselves in an equal time, and with the same degree of *impulsive force*, wherewith they were bent in this re-action, the motion that remained in the striking body will be totally destroyed, and the total exertion of the two springs, communicated to the original resting body, will cause it to fly off with the same velocity wherewith it was struck.

Upon this idea, if we could construct a couple of bodies in such a way that they should either act as bodies perfectly elastic; or, that their springs should at pleasure be hooked up, retained, or prevented from restoring themselves, when at their extreme degree of bending; and if the bodies under these

circumstances observed the laws of collision of non-elastic soft bodies, then it would be proved, that one half of the mechanical power, residing in the striking body, would be lost in the action of collision; because the impulsive force or power of the spring in its restitution being cut off, or suspended from acting, which is equal to the impulsive force or power to bend it (and which alone has been employed to communicate motion from one body to the other), it would make it evident, that one half of the impulsive force is lost in the action, as the other half remains *locked up* in the springs. It also follows, as a *collateral circumstance*, that be the impulsive power of the springs what it may from first to last, yet as one half of the *time* of the action is by this means cut off, in this sense also it will follow, that one half of the mechanic power is destroyed; or rather, in this case, remains locked up in the springs, capable of being *re-exerted* whenever they are set at liberty, and of producing a fresh mechanical effect, equivalent to the motion or mechanical power of the two non-elastic soft bodies after their collision.

Hence we must infer, that the quantity of mechanical power expended in displacing the parts of non-elastic soft bodies in collision, is exactly the same as that expended in bending the springs of perfectly elastic bodies; but the difference in the ultimate effect is, that in the non-elastic soft bodies, the power taken to displace the parts will be totally lost and destroyed, as it would require an equal mechanic power to be raised afresh, and exerted in a contrary direction to restore the parts back again to their former places; whereas, in the case of the elastic bodies, the operation of half the mechanic power is, as observed already, only locked up and suspended, and capable of being re-exerted without a further original accession.

These ideas arose from the result of the experiments tried upon the machine described in my said tract upon *Mechanic Power*, and were also communicated to my very worthy and ingenious friend WILLIAM RUSSELL, Esq. F. R. S. at the same time that I shewed him those experiments in 1759; but the mode of putting this matter to a full and fair mechanical trial has since occurred; and though some rough trials, sufficient to shew the effect, were made thereon, prior to the offering the paper on mechanical power to the Society in 1776, yet the machine itself I had not leisure to complete to my satisfaction till lately; which I mention to apologize for the length of time that these speculations have taken in bringing forward.

DESCRIPTION OF THE MACHINE FOR COLLISION.

Fig. 1. shews the front of the machine as it appears at rest when fitted for use.

A is the pedestal, and AB the pillar, which supports the whole, C, D are two compound bodies of about a pound weight each, but as nearly equal in weight as may be. These bodies are alike in construction, which will be more particularly explained by fig. 2. These bodies are suspended by two white fir rods of about half an inch diameter *ef* and *gb*, being about four feet long from the point of suspension to the center of the bodies; and their suspension is upon the cross-piece II, which is mortised through, to let the rods pass with perfect freedom; and they hang upon two small plates filed to an edge on the under side, and pass through the upper part of the rods. Their centers are at *k* and *l*, and the edges being let into a little notch, on each side the mortise, the rods are at liberty to vibrate freely upon their respective points (or rather edges) of suspension, and are determined to one plain of vibration. MN is a flat arch of white wood, which may be covered with

Paper, that the marks thereupon may be the more conspicuous.

The cross-piece II is made to project so far before the pillar, that the bodies in their vibrations may pass clear of it, without danger of striking it; and also the arch MN is brought so far forward as to leave no more than a clearance, sufficient for the rods to vibrate freely without touching it.

Fig. 2. Shews one of the compound bodies, drawn of its full size. AB is a block of wood, and about as much in breadth as it is represented in height, through a hole in which the wood rod CC passes, and is fixed therein.

DB represents a plate of lead about three-eighths of an inch thick, one on each side, screwed on by way of giving it a competent weight. *dBefg* represents the edge of a springing plate of brass, rendered elastic by hard hammering; it is about five-eighths of an inch in breadth, and about one-twentieth of an inch thick. It is fixed down upon the wooden block at its end *dB* by means of a bridge plate, whose end is shewn *hi*, and is screwed down on each side the spring plate by a screws which being relaxed the spring can be taken out at pleasure, and adjusted to its proper situation. *kl* is a light thin slip of a plate, whose under edge is cut into teeth like a fine saw or ratchet, and is attached to the spring by a pin at *k*, which passes through it, and also through a small stud rivetted into the back part of the spring, and upon which pin, as a center, it is freely moveable.

mn shews a small plate or stud seen edgeways raised upon the bridge plate, through an hole in which stud the ratchet passes; and the lower part of the hole is cut to a tooth shaped properly to catch the teeth of the ratchet, and retain it together with the spring at any degree to which it may be suddenly bent; and for this intent it is kept bearing gently downward, by means of a wire-spring *opq*, which is in reality double, the bearing

bearing part at *o* being semi-circular; from which branching off on each side the rod *cc*, passes to *p*, and fixes at each end into the wood at *q*. However, to clear the ratchet, which is necessarily in the middle as well as the rod, the latter is perforated; and also the block is cut away, so far as to set the main spring at *e* free of all obstacles that would prevent its play from the point *B*. The part *fg* is shewn thicker than the rest, by being covered with thin kid leather tight sowed on, to prevent a certain jarring that otherwise takes place on the meeting of the springs in collision.

Let us now return to fig. 1. the marks upon the arch *MN* are put on as follows. *op* is an arch of a circle from the center *l*, and *qr* an arch of a circle from the center *k* intersecting each other at *s*. Now the middle line of the marks *t*, *v*, are at the same distance from the middle line at *s* that the centers *kl* are; so that when each body hangs in its own free position, without bearing against the other, the rod *ef* will cover the mark at *t*, and the rod *gb* will cover the mark at *v*. From the point *S* upon the arches *Sp* and *Sq* respectively, set off points at an equal and competent distance from *S* each way, which will give the middle of the mark *w* and *x*: and upon the arch *Sp* find a middle point between the mark *v* and *w*, which let be *y*; and on the other side, in like manner, upon the arch *Sq* find a middle point for the mark *z*; then set off the distance *Sv* or *St* from *y* each way, and from *z* each way; and from these points, drawing lines to the respective centers *l* and *k*, they will give the place and position of the marks *a*, *b*, and *c*, *d*; and thus is the machine prepared for use.

FOR TRIALS ON ELASTIC BODIES.

For this use take out the pins and ratchets from each respectively, and the springs being then at liberty, with a short bit
of

of stick (suppose the same size as the rods) turn aside the rod gb with the right-hand, carrying the body D upwards till the stick is upon the mark w , as suppose at $\odot$; there hold it, and with the left set the body C perfectly at rest; in which case the rod ef will be over the mark t ; then suddenly withdraw the stick, in the direction that the rod gb is to follow it, and the spring of the body D , impinging upon that of the body C , they will be both bent, and also restored; and the body C will fly off, and mount till its rod ef covers the mark x ; the rod of the striking body D remaining at rest upon its proper mark of rest v , till the body C returns, when the body D will fly off in the same manner; the two bodies thus rebounding a number of times, losing a part of their vibration each time; but so nearly is the theory of elastic bodies fulfilled hereby, that the single advantage of originally pushing the rod gb beyond the mark w , by the thickness of the stick, or its own thickness, is sufficient to carry the rod of the quiescent body C completely to its mark x .

There are several other experiments that may be made with this apparatus, in confirmation of the doctrine of the collision of elastic bodies; which being universally agreed upon, and well known, it is needless further to dwell upon here; but respecting the application to non-elastic soft bodies, it is far more difficult to come at a fitness of materials for this kind of experiments, than it is for those supposing perfectly elasticity. The conclusions, however, may be attained with equal certainty.

FOR TRIALS ON NON-ELASTIC SOFT BODIES.

For this purpose the ratchets must be applied and put in order as before described, and the springs being both put to their point of rest, let the body D be put to its mark w in the
same

same manner as before described, and the body C to rest. The body D being let go, and striking the body C at rest, in consequence of the stroke, the springs being hooked up by the ratchets, they both move from their resting marks t, v , respectively toward M: Now if they both moved together, and the rod ef covered the mark c , and the rod gb covered the mark d at their utmost limit, then they would truly obey the laws of non-elastic soft bodies; because their medium ascent would be to the mark z , which is just half the angle of ascent to the mark x ; but as in this piece of machinery, though the main or principle springs are hooked up, yet every part of them, and all the materials of which they are composed, and to which they are attached, have a degree, or more properly speaking, a certain compass of *elasticity*, which, as such, is perfect, and no motion lost thereby.

We must not, therefore, expect the two compound bodies after the stroke to stick together without separating, as would be the case with bodies truly non-elastic and soft; but that from the elasticity they are possessed of, they will by rebounding be separated; but that elasticity being perfect, can occasion no loss of motion to the sum of the two bodies; so that if the body C ascends as much above its mark c as the body D falls short of its mark d , then it will follow, that their medium ascent will still be to the mark z , as it ought to have been, had they been truly non-elastic soft bodies; and this, in reality, is truly the case in the experiment, as nearly as it can be discerned.

After a few vibrations, by the rubbing of the springs against one another, they are soon brought to rest; and here they would *always rest* had they been truly and properly perfect non-elastic soft bodies; but here, as in the case of these bodies, by a change of the figure and situation of the component parts, there is expended one half of the mechanical power

of the first mover, yet in this case the other half is not *lost*, but *suspended*, ready to be re-exerted whenever it is set at liberty; and that it is really and *bona fide one half* and neither more or less, appears from this uncontroverted simple principle, that the power of restitution of a perfect spring is exactly equal to the power that bends it. And this may, in a certain degree, be shewn to be fact by experiment, if there were any need of such a proof; for if, when the bodies are at rest after the last experiment, the two rods are lashed together near the bottom with a bit of thread, and then the ratchets unpinned and removed; on cutting the thread with a pair of scissars they will each of them rebound, C towards M, and D towards N; and if they rebounded respectively to x and y , the mechanical power exerted would be the same as it was after the stroke, when the mean of their two ascents was up to the mark x ; but here it is not to be expected, because not only the motion lost by the friction of the ratchets is to be deducted, because it had the effect of real non-elasticity; but also the elasticity that separated them in the stroke, which was lost in the vibrations that succeeded; neither of which hindered the mean ascent to be to x ; but yet, under all these disadvantages in the machine (if not unreasonably ill made) the rod *ef* will ascend to *d*, and *gb* to *a*: and hence I infer, as a positive truth, that in the collision of non elastic soft bodies, *one half of the mechanic power residing in the striking body is lost in the stroke.*

Respecting bodies unelastic and perfectly hard, we must infer, that since we are unavoidably led to a conclusion concerning them, which contradicts what is esteemed a truth capable of the strictest demonstration; *viz.* that the velocity of the center of gravity of no system of bodies can be changed by any collision betwixt one another, something must be assumed that involves a contradiction. This perfectly holds, according

according to all the established rules, both of perfectly elastic and perfectly non-elastic *soft* bodies; rules which must fail in the perfectly non-elastic *hard* bodies, if their velocity after the stroke is to the velocity of the striking body as one is to the square root of 2; for then the center of gravity of the two bodies will by the stroke acquire a velocity greater than the center of gravity the two bodies had before the stroke in that proportion, which is proved thus.

At the outset of the striking body, the center of gravity of the two bodies in our case will be exactly in the middle between the two; and when they meet it will have moved from their half distance to their point of contact, so the velocity of the center of gravity before the bodies meet will be exactly one half of the velocity of the striking body; and, therefore, if the velocity of the striking body is 2, the velocity of the center of gravity of both will be one. After the stroke, as both bodies are supposed to move in contact, the velocity of the center of gravity will be the same as that of the bodies; and as their velocity is proved to be the square root of 2, the velocity of their center of gravity will be increased from 1. to the square root of 2.; that is, from 1. to 1.414, &c.

The fair inference from these contradictory conclusions therefore is, that an unelastic hard body (perfectly so) is a repugnant idea, and contains in itself a contradiction; for to make it agree with the fair conclusions that may be drawn on each side, from clear premises, we shall be obliged to define its properties thus: that in the stroke of unelastic hard bodies they cannot *possibly lose any* mechanic power in the stroke; because no other impression is made than the communication of motion; and yet they *must lose a quantity* of mechanic power in the stroke; because, if they do not, their common center of gravity, as

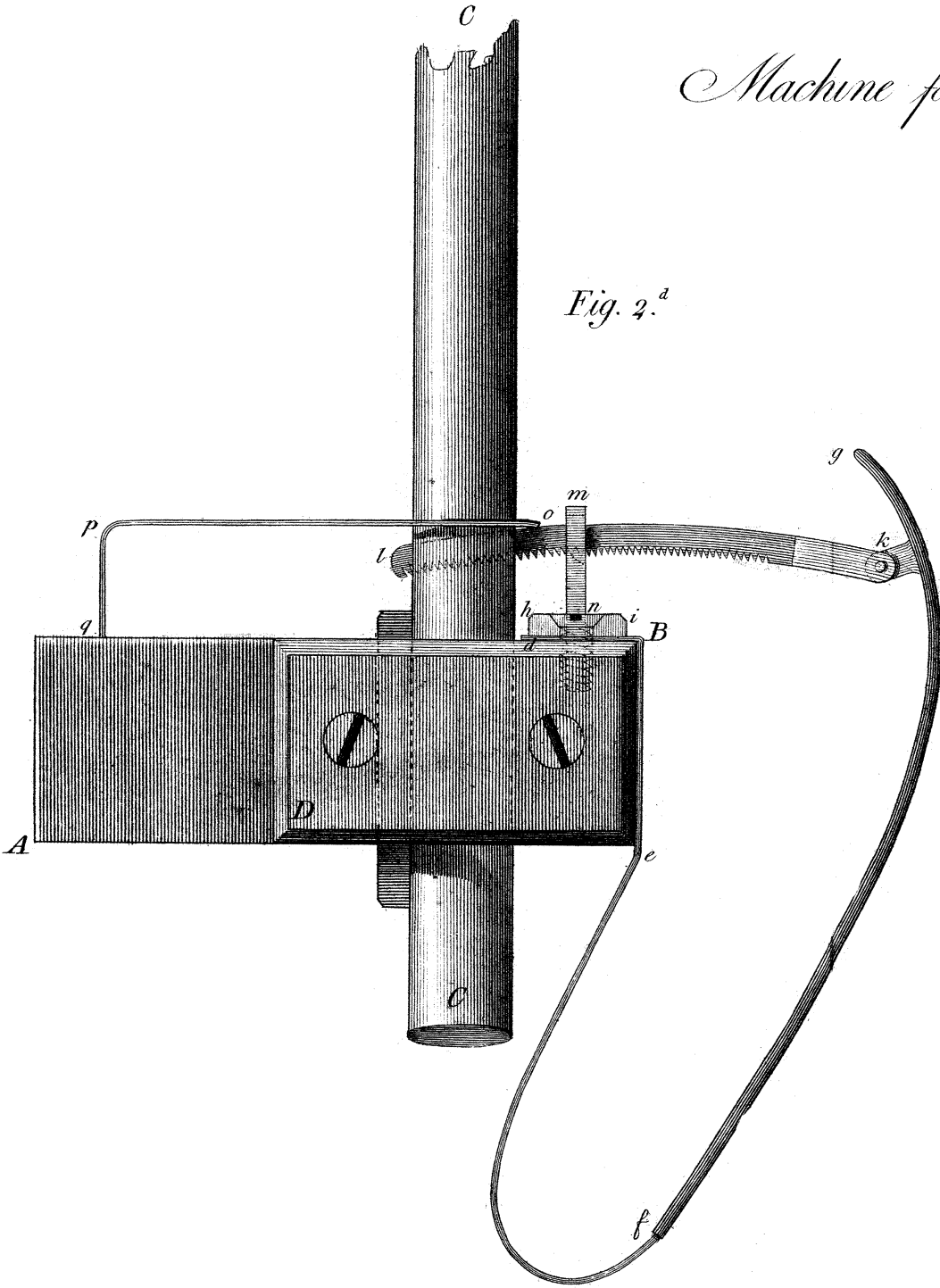
above shewn, will acquire an *increase* of velocity by their stroke upon each other.

In a like manner the idea of a *perpetual motion*, perhaps, at first sight, may not appear to involve a contradiction in terms; but we shall be obliged to confess that it does, when, on examining its requisites for execution, we find we shall want bodies having the following properties; that when they are made to *ascend* against gravitation their absolute weight shall be *less*; and that when they *descend* by gravitation (through an equal space) their absolute weight shall be greater; which, according to all we know of nature, is a *repugnant* or *contradictory idea*.



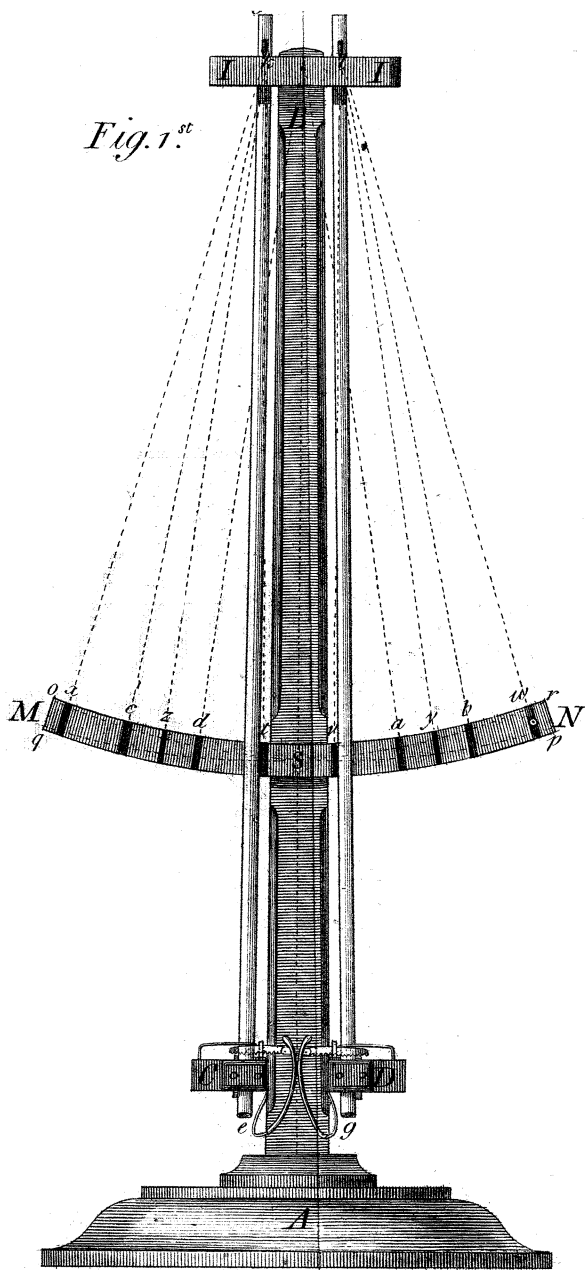
Machine for COLLISION

Fig. 2.^d



VISION ~

Fig. 1st



Scale of Feet.

12 In. 0

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Machine for COLLISION.

Fig. 2.^d

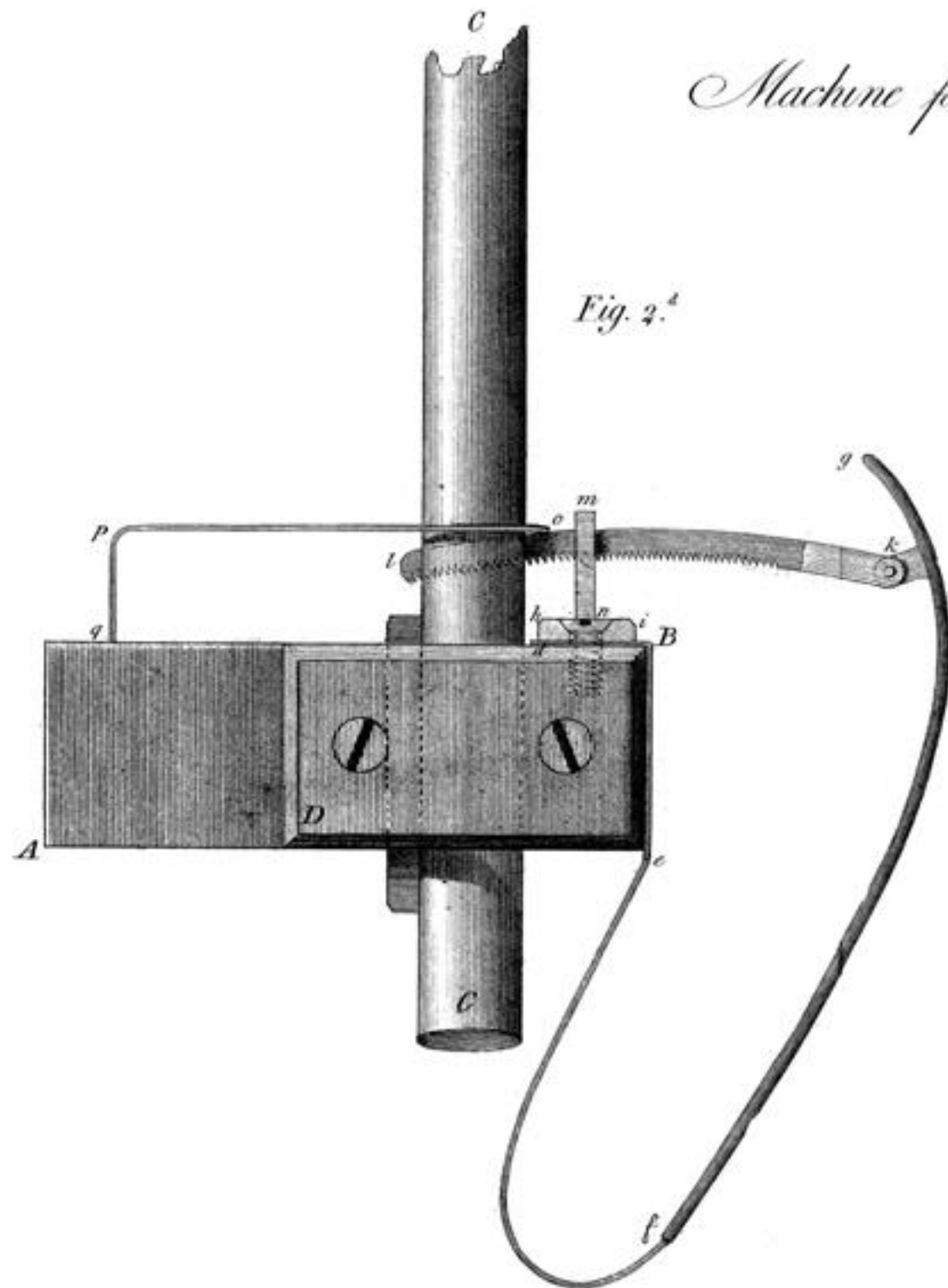
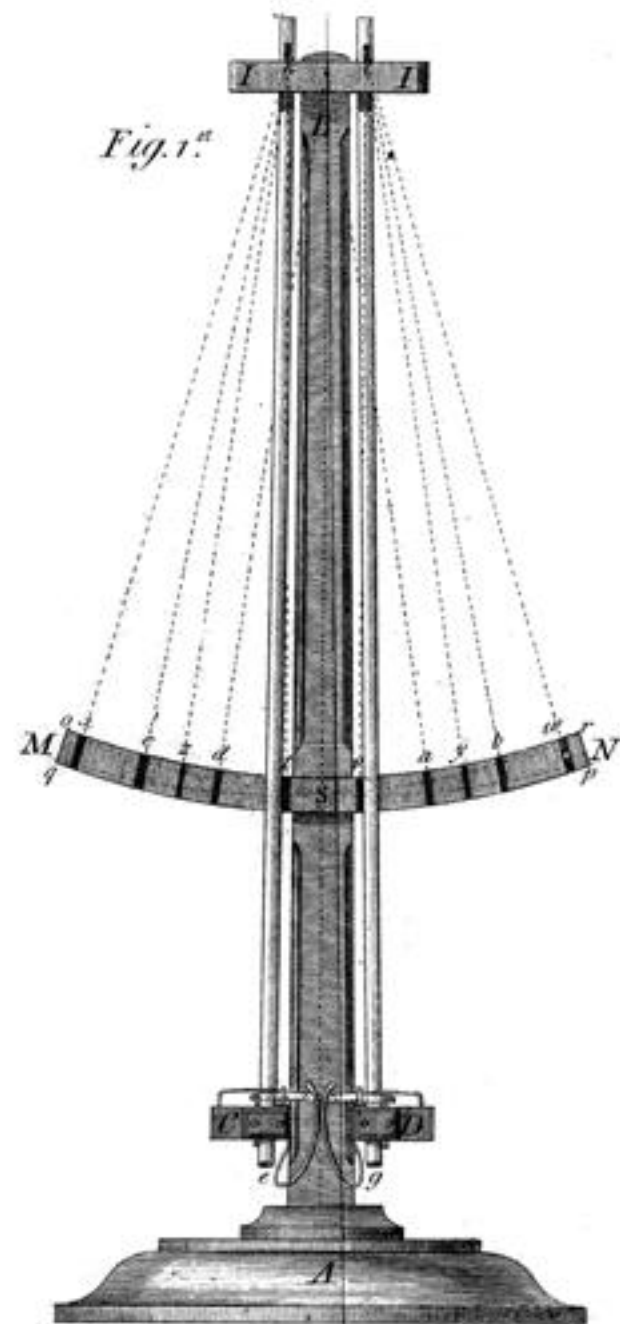


Fig. 1.^a



Scale of Feet.

